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Further Testing of an Eddy Current Separator for the Recovery of Aluminum from Municipal Waste Test No. 5.02, Recovery 1, New Orleans

National Center for Resource Recovery, Inc.
Washington, DC

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FURTHER TESTING OF AN EDDY CURRENT SEPARATOR FOR THE RECOVERY OF ALUMINUM FROM MUNICIPAL WASTE

Test No. 5.02, Recovery 1, New Orleans

by

National Center for Resource Recovery, Inc.
Washington, D. C. 20036

Contract No. 68-01-4423

Project Officer

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16. ABSTRACT

This report documents three series of test runs (collectively, Test No. 5.02) of the eddy current separator that recovers mainly aluminum cans from a processed portion of municipal refuse at the New Orleans resource recovery project (Recovery 1). This was accomplished by holding the feed rate constant and varying the belt speed to convey the fixed amount of material through the magnetic field faster or slower. For comparison, there is also one test run at each belt speed with only aluminum feed cans as the feedstock. The output streams of the eddy current separator from each test were analyzed for aluminum can content in three can-shape categories; the product stream was also analyzed for contamination. The efficiency of the eddy current separator in recovering each can-shape category as well as product purity were determined for each test run.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of waste water and solid and hazardous waste pollutant discharges from municipal and community sources; for the preservation and treatment of public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report documents a test of the eddy current separator used to recover principally aluminum cans from a processed portion of municipal refuse at the New Orleans Resource Recovery Project (Recovery 1). It is hoped that this report yields data and other information that is useful to those considering aluminum recovery from municipal refuse through mechanical processing.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

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ABSTRACT

This report documents three series of test runs (collectively, Test No. 5.02) of the eddy current separator that recovers mainly aluminum cans from a processed portion of municipal refuse at the New Olreans resource recovery project (Recovery 1). Each of the three test series consisted of two replicate test runs. The burden on the eddy current separator conveyor, i.e., the amount of material in the magnetic field at any one period of time, differed. This was accomplished by holding the feed rate constant and varying the belt speed to convey the fixed amount of material through the magnetic field faster or slower. For comparison, there is also one test run at each belt speed with only the aluminum feed cans as the feedstock. The output streams of the eddy current separator from each test were analyzed for aluminum can content in three can-shape categories; the product stream was also analyzed for contamination. After completion of the six complete feedstock test runs, the non-aluminum can portion of the test feedstock was analyzed for rag-like items, particle size, and moisture content. The efficiency of the eddy current separator in recovering each can-shape category as well as product purity were determined for each test run. The report details the results of the test runs and the analyses and also describes the eddy current separator and the test and analytical procedures used.

This report was submitted in partial fulfillment of Contract No. 68-01-4423 by National Center for Resource Recovery, Inc., under the sponsorship of the U. S. Environmental Protection Agency and covers a period from June 16 to June 20, 1980, with data analysis and reporting completed as of July 1980.

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SECTION 1

INTRODUCTION AND SUMMARY OF TEST RESULTS

There is an aluminum recovery submodule at Recovery 1 in New Orleans for the removal, cleanup, and densification of aluminum, primarily cans, found in the municipal solid waste (MSW). Installed separation equipment that impacts on the efficiency of the overall system is, in order - starting farthest upstream:

(1) a large trommel which separates unprocessed refuse into +4-3/4" and -4-3/4" fractions [1] or for the alternate processing line, a horizontal-shaft shredder which reduces the refuse to -4" nominally;

(2) a scalping magnet for the trommel unders or for the alternate processing line, a scalping magnet for the shredded refuse;

(3) an air classifier which blows a portion of light organics away from the scalped -4-3/4" trommel unders or shredded refuse;

(4) a two-deck flat vibrating screen which separates the air-classified heavies into three parts (+5" dia. discards, -5" dia. +2" material which is the aluminum submodule feedstock, and -2" material which is the glass submodule feedstock) [2];

(5) a second 2" flat-deck screen which processes the aluminum submodule feedstock to increase the removal of -2" material; and

(6) a scavenging magnet to remove any tramp magnetic metal;

Next comes the eddy current separator, called an Al Mag, which removes the aluminum cans from the feedstock. Aluminum cans usually represent about 3 to 5%, by weight, of the Al Mag feed from the primary processing line. There is very little other aluminum or other nonferrous metal in this feed. The Al Mag product is usually greater than 90%, by weight, aluminum. The remainder of the product is organics and inorganics, with a

few occasional pieces of nonferrous metal that are not aluminum cans. Downstream of the Al Mag are two pneumatic separators, an air classifier, and an air knife, whose purposes, sequentially, are to (1) fly the light organics from the Al Mag product [3], and (2) then blow the aluminum cans beyond the heavy organics, inorganics, and nonferrous metal that were also carried over as part of the product. The output of interest from the pneumatic separators is the one with the aluminum cans. Finally, there is a shredding step which tears the cans into smaller pieces mainly to increase their density for shipping. After shredding and before shipping, -12 mesh fines are removed from the shredded aluminum product by a vibrating screen.

The Al Mag is the subject of this report. This device manufactured by Combustion Power Company, operates on the principle that an electric current is generated in each conductor (piece of metal) passing through an electromagnetic field. These "eddy currents" have a magnetic field which interacts with the applied field and produces a lateral force on the metal. This force expels the nonferrous (non-magnetic) metal from the conveyor which carries the feed through the magnetic field. There is some carryover, or entrainment, of organics, etc., as mentioned above.

The objectives of the previous test [4] were to measure differences in efficiency and product rate which accompany an accelerated Al Mag throughput with burden held constant. For that test, three operating points were described which differed only in the amount of time an individual piece of aluminum was in the magnetic field and was subject to being repelled out of the burden of the feedstock, i.e., to become Al Mag product. With the exception of this active time variable, an attempt was made to hold all other parameters constant, including, as mentioned, the burden on the Al Mag conveyor. The importance of the results of varying the active time was to determine whether this relatively expensive piece of equipment could be run at higher throughput levels without suffering major losses in efficiency.

If the Al Mag efficiency did not fall off more rapidly than the increase in the number of recovery opportunities, i.e., the aluminum feed rate, the product rate for a given period of time would actually rise. Indeed, because of time constraints on processing waste at Recovery 1 and the cost of adding a second shift for the recovery portion of the operation, it would be preferable to accept the loss in efficiency as long as more aluminum could be recovered during the manned first shift.

The results of these previous test runs indicated, as would be expected, that increasing the throughput did decrease efficiency; however, product rate increased. For example, the decrease in efficiency (18.5%) going from 2 to 4 tph was more than compensated by the doubling of the number of aluminum can recovery opportunities. Based on the test runs which were conducted with approximately a 5%, by weight, aluminum can concentration, the product rate in the 2 to 4 tph example rose from approximately 175 pounds per hour (lb/hr) to 280 lb/hr.

The tests reported here are a follow-on. Most of the -2" light material, a fraction that made up approximately half of the earlier feedstock, was screened out. In these tests, the burden was also varied systematically, being less for the faster belt speeds. The objectives of this Al Mag test then was to measure differences in Al Mag efficiency, product rate, and product quality which accompany changes in the composition of the feedstock, conveyor belt speed and consequently, burden depth. The first test (No. 5.01) results provided a nominal starting point for the current series: volumetric flow of 900 ft^3/min at 400 fpm conveyor speed (0.3" burden).

The results of the test runs in the new test, compared to each other, indicate only a fairly small effect on Al Mag efficiency (five percentage units) and virtually no effect on product quality as the belt speed was varied. Two test runs were made for each belt speed. Eighty pounds of feedstock per run were used. The belt speeds selected were 300 fpm, 400 fpm (same as maximum volumetric feed rate in the previous test), and 500 fpm. Al Mag efficiencies for the three belt speeds were 90.6% (300 fpm), 85.3% (400 fpm), and 86.1% (500 fpm). The product contamination was 11.9, 10.5, and 12.7%, respectively.

Significant differences emerge when the results of the new test and the old series are compared. The data given above corresponds to 76.9% (300 fpm) and 65.9% (400 fpm) for the comparable belt speeds from the previous test. As mentioned, for these tests, the burden was maintained constant. This had the effect of increasing the aluminum can recovery opportunities per unit of time when belt speed was increased. For the second series, speeding up the belt only spread the material out. The aluminum opportunity stayed the same. Adjusting the second test results to account for greater aluminum opportunity which was present in the earlier test series, yields product rates of 396 lb/hr for the 300 fpm runs and 373 lb/hr for the 400 fpm runs. The sample cans, although the same in number for the two test series, were 12% lighter in the current test (390 lb/hr compared to 428 lb/hr). This is the reason for the adjustment.

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Product rates between the two series of tests turn out to be significantly different. In the earlier test, 300 fpm produced 249 lb/hr. In the second series, 300 fpm yielded 396 lb/hr. For the 400 fpm runs, the comparable figures were 280 lb/hr and 373 lb/hr. Therefore, there appears to be a distinct benefit derived from screening out as much -2" material as possible. One does not lose any aluminum in doing this as there is virtually no aluminum in this size range. Therefore, -2" material simply contributes to the burden.

There were a number of differences between the two tests. While the aluminum can concentration in the feed was the same, by volume, as that used in the previous test, the non-aluminum portion of the feedstock had a lower bulk density - much drier - than that used in the earlier test. Therefore, the weight concentration of aluminum cans was 12.2% rather than 5.5%. The composition of the seed cans, by shape, was the same as that used earlier, which parallels that found normally in the Al Mag feed. The non-aluminum portion of the feedstock was prepared from shredded refuse (that had not been air classified) by two screenings across a 2-1/4"-diameter opening screen and removal by handpicking of +5" diameter material and all metals. Flexible items that would pass through a 5"-diameter opening were not removed. Except for replacement of representative feedstock for small losses between runs, the same feedstock was reused for each test run. In the earlier tests the feedstock came from air-classified trommel unders which would be more dense even at the same moisture level.

The system in New Orleans does not have sufficient screening surfact to remove even the bulk of the -2" organics from the Al Mag feed. One purpose of the test was to develop estimates of the value of increasing screening on this material. The hand screening done in preparing the feed material had the desired effect of removing approximately half of this material, which amounted to 67%, by weight, of the feedstock in the -2" material that remains is somewhat wetter than +2". Therefore, when there is less of it in any given volume of feedstock and the volume of aluminum is kept constant, the weight percentage of aluminum rises. This accounts for some of the increase in weight percentage of aluminum, but the main reason is that the non-aluminum material overall was lighter and fluffier. It was easier to carry over into product, which, therefore, is the reason for the higher contamination level in the product compared to the previous test series.

The three aluminum can-shape categories were flattened, deformed, and whole. The composition (wt) of the 256 feed cans used was 18% flattened, 71% deformed, and 11% whole.

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The cans in the deformed category differed from those used in the previous test because they consisted only of those with one end and part of the body flattened rather than a range of shapes between flattened completely and undeformed, or whole. This could have had an important effect as most of the cans in the sample were in this shape category. Also the differences in recovery were the greatest between the two test runs in the case of the deformed cans. As before, a larger proportion of the whole cans were recovered compared to the other shapes.

From the tests it can be concluded that the effect of reducing burden depth (by running the belt faster) does not compensate for the loss of time in the magnetic field and in the time to leave the belt (the trade-off), and that for a constant feed rate it is advantageous to slow down the belt. The tests also highlight the probable advantage of screening out as much non-aluminum-bearing material as possible, i.e., the -2" fraction. Unfortunately, this result is confounded by the fact that only about 15% of the weight of the feedstock during the current test runs was attributed to moisture, while slightly over 40% was moisture in the earlier runs. This led to volumetric limitations at relatively low throughputs (1.6 tph rather than 4 tph at 400 fpm belt speed). There were also fewer flexibles in the second test series. For this reason, the two tests are not completely comparable.

In addition to the test runs with full feedstock, a test run for each belt speed was made with only seed cans, i.e., no burden. The cans were consistently recovered at higher efficiency. This yields a measure of the impediment provided by the burden. The difference in efficiency - with and without burden - was fairly consistent at about eight percentage units.

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SECTION 2

EQUIPMENT DESCRIPTION, FEEDSTOCK MAKEUP, TEST PROCEDURE, AND SAMPLE ANALYSES

EQUIPMENT DESCRIPTION

Prior to entering the waste-receiving building, all refuse collection and transfer vehicles are weighed and recorded. In the receiving building, unprocessed MSW is deposited on the tipping floor where a front-end loader directs the waste onto either of two conveyor lines, designated Line No. 1 and Line No. 2.

From Line No. 1, the refuse is conveyed into a trommel which is designed to remove small objects and to break open plastic and paper bags, as well as to reduce shredder wear and maintenance. The trommel is 9.75' in diameter, 45' long, with 4-3/4" circular holes in the barrel. Most of the material less than 4-3/4" passes through the trommel holes (designated trommel underflow), and is conveyed to a magnetic-drum separator for removal of ferrous, primarily tin-plated steel cans. The remaining material after magnetic scalping is then directed to an air classifier for further processing, or diverted to trailers for landfilling. The material larger than 4-3/4" passing through the trommel (designated trommel overflow) is conveyed to a vertical-shaft Heil shredder for size reduction to 4", nominal. Via a separate conveyor, the shredded material is transported to a second magnet, with the tailings directed to landfill.

From Line No. 2 in the receiving building, refuse is conveyed to a horizontal-shaft Gruendler shredder for size reduction to 6", nominal, then conveyed to the shredded material magnet. The tailings are usually directed to landfill, with the alternative of air classification and recovery of aluminum and glass.

The air classifier separates aerodynamically light materials, primarily paper, plastics, and textiles, from heavier materials such as glass, aluminum and other nonferrous, and some heavy organics. The air-classified light material is conveyed to the Recovery Building for further materials recovery

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In a previous test, only trommel underflow, after magnetic separation and air classification, was used to produce test feedstock material [4], whereas, in this current test, only shredded MSW was used to produce the feedstock.

Normally, the air-classified heavy material is conveyed onto a 6' x 10' double-deck vibrating flat screen, which separates the material into three output streams: +5" discards, -5" +1" aluminum submodule feedstock, and -1" glass submodule feedstock. In addition to a 5" round hole screen, the top deck consists of six raised parallel "grizzly" bars, each 6'-8' long angle iron that are spaced with 5" clear openings. Some paper and rags are caught on the bars and are vibrated down the screen and discharged for landfilling. The lower screen deck is punched-plate with 1-1/4" round holes. The -1-1/4" material from the screen, about 50% (wt.) organics with the rest primarily glass with some stones and ceramics, is conveyed to the glass recovery submodule. Formerly, this screen had a 2" square-opening bottom deck.

The -5" +1-1/4" material remains in the aluminum submodule. It consists primarily of paper, leaves, grass, plastics, textiles, wood, rubber, etc. About 2%, by weight, is aluminum cans.

The -5" +1-1/4" stream passes to a second vibrating screen, which uses grizzly bars to remove some of the long, stringy material like bread wrappers and a 2-1/4" circular opening punched plate deck below the grizzlies to remove the remaining finer material.

The remaining -5" +2-1/4" material (some -2-1/4" material remains also) from this vibrating screen passes a rotating drum magnet. This magnet is located directly upstream of the eddy current separator's vibrating feeder and is intended to remove residual, or tramp, ferrous metal that can interfere with the operation of the Al Mag. This magnetically cleaned material then drops onto the vibrating pan conveyor, which in turn feeds the Al Mag.

The eddy current separator tested, an "Al Mag 20" manufactured by Combustion Power Company, was designed to recover the non-magnetic metallic material, primarily aluminum products, from a feedstock prepared generally as described above. The Al Mag 20 is an eddy current separator that uses electromagnetic forces, created by a poly-phase current source, as a method of sorting. When a piece of conductive nonferrous (and thus non-magnetic) metal such as aluminum passes through the magnetic field generated by the applied current, eddy currents are generated in the metal. These eddies produce their

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own electromagnetic field which interacts with that from the applied field. The two electromagnetic fields repel each other, and thus produce a force that levitates and repels the non-ferrous metal. By arranging the electromagnetic fields perpendicular to the flow of material, these forces cause non-ferrous metals to move perpendicular to material flow. Thus, in the Al Mag, nonferrous metals are rejected off both sides of the conveyor belt, in a direction perpendicular to the direction of belt travel. The force on a given non-magnetic material depends on its electrical conductivity and mass density. Aluminum is preferentially separated but is not the only metal separated.

The Al Mag utilizes four pairs of water-cooled electromagnets arranged about a 24"-wide conveyor. Magnets are arranged so that two pairs of magnets cover slightly more than each half of the belt. The first two pairs remove material from one half of the belt, while the other two pairs are located downstream of the first pair and remove material from the other half of the belt. The top part of each magnet pair has five poles; the bottom part has four poles. The air gap (clear area that the feed material flows through between the electromagnets) is variable. For the series of tests reported here, the gap was 3-7/8". Because there is occasional clumping of the feed material, a plow device is provided at the entry section to realign or deflect any oversize material to collection chutes at the sides of the separator.

The magnets utilize three-phase 480-volt electricity. Power consumption is about 27 kilowatts. The electrical circuits for two pairs of magnets at a time are switched off at one-minute staggered intervals for two or four seconds to prevent any tramp magnetic metal which escaped the magnetic separators from constricting the material flow. The electromagnets are water-cooled, using a water flow of about 135 gallons per hour. At this flow, the cooling water temperature normally rises about 68° as it cools the magnets.

The Al Mag conveyor belt speed is variable from 150 to 725 feet per minute (fpm). The belt is a slider-type configuration, 0.075" thick nylon with a stainless steel splice.

The Al Mag 20 is sized to continuously process a maximum of 900 ft^3/hr and is rated to recover 75% of essentially whole aluminum cans, with less than 50% loose contamination in the product, from 3.85 tph of 8.5 to 11 lb/ft^3 feed material derived from trommel unders and processed as described above. Trommel unders result when Line No. 1 is running. For Line No. 2 which does not have a trommel, but only a shredder, the rating is for 75% recovery of shredded cans, with less than 40% loose contamination in the product, from 1.6 tph of feed material.

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The Al Mag "product" is conveyed into an air classifier, with the "heavy" fraction dropping into an air knife. The air classifier is designed to pneumatically remove the "light" organics while the air knife separates the relatively light-mass cans from the heavier organics and nonferrous metals.

This light-mass aluminum canstock is shredded in a small hammermill to -1" circular to increase bulk density to 15-25 lb/ft^3 for shipping. Prior to loading for shipment, the shredded aluminum is screened (vibrating) to remove -12m fines from the product. The resulting salable aluminum product is pneumatically conveyed to storage prior to shipment.

FEEDSTOCK MAKEUP

The nonaluminum can portion of the feedstock used in the test runs was prepared from shredded refuse collected from Line No. 2. Approximately two cubic yards of shredded refuse was screened on the 2-1/4" circular opening deck of the vibrating screen described above. The +2-1/4" portion was collected and re-screened to remove residual -2-1/4" material. The twice-screened material was then handpicked to remove all metals and any items that would not pass a 5" circular opening. The remaining material, after the two screenings and handpicking, constituted the nonaluminum can portion of the feedstock that was reused for each test run with the exception of the small quantity (<5%) added to successive runs to offset the losses to the scavenger magnet product and the Al Mag product and plowovers as well as moisture loss due to evaporation. There was some reduction in particle size due to handling for each run but neither this change nor the above loss/replacement was substantial enough to affect the test results.

From the previous test of the Al Mag, composition, by shape, of aluminum cans in the Al Mag feed had been determined to be 18% flattened (both ends and body crushed flat), 71% deformed (one end and part of body flattened), and 11% whole (essentially intact with no substantial deformations). This composition for Al Mag test was used to prepare the seed cans for the current test series, as summarized in Table 1. All of the seed cans were 10 oz capacity beverage cans of 17-1/4g average weight. With the exception of an occasional replacement of a lost seed can, the same cans were resued in each test run.

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TABLE 1. SEED CANS USED IN TEST RUNS

Can Type	Number	Weight	%
Flattened	45	1.71	18
Deformed	182	6.92	71
Whole	29	1.10	11
Total	256	9.74	100

6-1/2"

TEST PROCEDURE

For each run, the 70.3 pounds of non-aluminum can feedstock were weighed into six equal portions. The 9.7 pounds of aluminum seed cans were divided equally (by number) among the types into six portions and randomly distributed in the non-can feedstock in a trash container. The trash containers were then emptied by hand into the chute immediately preceding the scavenger magnet according to the appropriate time schedule, i.e., one trash container full every 15 seconds for a mass feed rate of 1.6 tph and an approximate volumetric feed rate of 835 ft^3/hr (approximately the same volumetric feed rate as in the 4 tph test runs of the previous Al Mag test which used Line No. 1-derived feedstock). The aluminum opportunity or feed rate for this test was a constant 390 lb/hr. For the comparable 300 and 400 fpm runs of the earlier test, the aluminum opportunity was 328 and 438 lb/hr, respectively.

For the current test series, only the Al Mag conveyor belt speed was varied. The belt speeds used were: 300, 400, and 500 fpm. Ignoring the inherent variability of hand feeding and slight changes in feedstock mentioned above:

(1) the non-aluminum can portion of the feed was the same;
(2) the aluminum cans were the same; and
(3) the mass and volumetric flow rates were the same for each run.

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Only the burden depth varied as the Al Mag conveyor belt speed was varied. The average burden depths, across the 18" of active belt width were approximately 3/8" at 300 fpm, 9/32" at 400 fpm, and 7/32" at 500 fpm. The approximage burden on the belt for all runs of the previous test series was 9/32". In all cases, the average burden is only a construct. Clumping always occurs on the belt, and many particles exceeded the average depth in three dimensions, including most of the aluminum seed cans.

Two test runs were executed at each of the three conveyor speeds. Also, a single test run was executed at each conveyor speed with seed cans alone; all other conditions were identical.

Because the feed point for the test runs was the inlet to the scavenging magnet, it was possible for can and non-can feed material to report to the magnet product or to the Al Mag plow-overs. The plow is a feature that evens the feed and helps to prevent jams in the Al Mag. These losses in Al Mag feed were very small in all test runs, with not more than two cans out of 256 reporting to both discharges in any one run.

SAMPLE ANALYSES

Immediately after each run, the Al Mag product was taken to the laboratory and sorted into the three can-shape categories and three contamination categories: +2" light contaminants (which should "fly" during subsequent air classification), -2" light contaminants (also should fly), and heavies (should "fall" in air classifier). The purpose of this categorization was to estimate the amount of contamination which would be found in the final aluminum recovery system product. Recall that there are two pneumatic cleanup steps after the Al Mag. The sorted cans were counted and the sorted non-can material was weighed.

The Al Mag throughs were spread out, and the "missed" seed cans retrieved, sorted into the three can-shape categories, and counted. The scavenger magnet product and Al Mag plowovers were sorted into the three can-shape categories and a non-can category; the cans were counted and the non-can material was weighed. Checks were made by summing the number of seed cans from all system discharge streams. When the can total was reconciled, the seed can sample portions were reconstituted, the reapportioning of the non-can feedstock for the next test was begun and the procedure described above was repeated.

After the test runs were completed, the count, weighing and the drying of the "flexibles" was done. A subsample of the remaining non-seed can material (1/16th of total) was prepared by cone and quartering. This subsample was screened to

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establish the proportion greater than 2" and less than 2" (square openings). These two size fractions were then dried at 104°C to determine the moisture content of each. These data appear in Section 3.

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SECTION 3

TEST RESULTS

The previous test of the Al Mag [4] was designed to measure Al Mag performance as the feed rate was varied while maintaining a constant conveyor burden depth (i.e., varying the Al Mag conveyor speed in proportion to the feed rate). As a suggested follow-on from that previous test, the current test series investigated Al Mag performance as the average burden depth on the Al Mag conveyor was varied, by changing the belt speed, while maintaining a constant feed rate (burden depth could also be varied by varying the feed rate while maintaining a constant conveyor speed). Al Mag performance in the current series was affected then by the varying belt speed and the varying burden depth. Varying belt speed affects the time an aluminum can resides in the magnetic field and its time available to discharge into the product chute; whereas, the varying burden depth affects the degree of impediment to its leaving the conveyor as well as the amount of contamination carried out. These two variables were likely to have offsetting effects on Al Mag efficiency (recovery of aluminum cans); in the current test this appeared to be the case.

The feed rate selected for the current test series approximated the estimated maximum permissible volumetric feed rate for the Al Mag, i.e., 900 ft^3/hr; the corresponding mass flow rate with the prepared feedstock was 1.6 tph. The seed can rate was about the same as in the maximum feed rate (4 tph) used in the previous Al Mag test; therefore, because the density of the non-can material was lower in the current test, the aluminum can weight percentage was higher, i.e., 12.2% rather than 5.5%. The maximum Al Mag conveyor belt speed used for the previous maximum feed rate test was 400 fpm; that speed and one higher and one lower (500 and 300 fpm) were selected for the current test series.

Data for the recovery of aluminum cans, i.e., Al Mag efficiency, are displayed in Table 2, and for Al Mag aluminum product rates, in Table 3. The amount of non-aluminum carryover, i.e., loose contamination, in the Al Mag product is displayed in Table 4. Finally, Table 5 shows several characteristics of the Al Mag feedstock used in the test.

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TABLE 2. Al MAG EFFICIENCY (Number Percent)

Al Mag Belt Speed	Flatte... Cans	Deformed Cans	Whole Cans	Overall
At 300 fpm				
Run 1	88.9	89.6	96.6	90.2
Run 2	91.1	91.1	89.3	90.9
Composite (1 & 2)	90.0	90.3	93.0	90.6
Seed cans only	97.7	98.4	100	98.4
At 400 fpm				
Run 1	68.2	84.1	100	83.1
Run 2	90.7	85.2	96.6	87.4
Composite (1 & 2)	79.3	84.6	98.3	85.3
Seed cans only	100	98.4	92.9	98.0
At 500 fpm				
Run 1	89.4	85.2	93.1	86.8
Run 2	79.1	85.6	93.1	85.3
Composite (1 & 2)	84.4	85.4	93.1	86.1
Seed cans only	90.7	95.0	96.6	94.5

NOTE: Cans lost as plowovers and to the ferrous magnet reject chute are not counted in the calculation. In the strictest sense, they would be counted in determining system efficiency. The table here refers only to Al Mag efficiency.

TABLE 3. AL MAG PRODUCT RATE (lb/hr)

Al Mag Belt Speed	Flattened Cans	Deformed Cans	Whole Cans	Overall
At 300 fpm				
Run 1	61	248	43	351
Run 2	62	249	38	350
Composite	62	249	40	351
Seed cans only	64	272	44	380
At 400 fpm				
Run 1	46	233	44	322
Run 2	59	236	43	338
Composite	52	234	43	330
Seed cans only	67	272	40	379
At 500 fpm				
Run 1	64	236	41	341
Run 2	52	234	41	327
Composite	58	235	41	334
Seed cans only	59	262	43	364

NOTE: Computed from actual cans recovered and time fed. In this computation, plowover losses and aluminum lost to the ferrous magnet discharge chute are indeed losses. For this reason, there is not a strict mathematical comparability between Tables 2 and 3.

TABLE 4. AL MAG PRODUCT CONTAMINATION
(Measured on As-Received Weight Basis)

Belt Speed	Loose Contamination (lb/hr) +2" Lights	-2" Lights	Heavies	Total	Percent of Product All	Lights
At 300 fpm						
Run 1	21.5	7.8	17.1	46.4	11.7	7.7
Run 2	27.9	6.7	13.6	48.2	12.1	9.0
Composite	24.7	7.3	15.4	47.3	11.9	8.3
At 400 fmp						
Run 1	34.2	9.0	5.7	48.9	13.2	11.8
Run 2	10.9	7.9	10.0	28.8	7.9	5.3
Composite	22.6	8.4	7.9	38.8	10.5	8.6
At 500 fpm						
Run 1	24.5	9.6	19.1	53.1	13.5	9.1
Run 2	26.3	5.5	12.3	44.1	11.9	8.9
Composite	25.4	7.5	15.7	48.6	12.7	9.0

TABLE 5. CHARACTERISTICS OF AL MAG FEEDSTOCK USED IN TEST

Size	Component	Composition (wt. Percent, As-Tested or Wet Basis)	Percent Moisture (Wet Basis)	Composition (wt. Percent, Dry Basis)
+2"	Aluminum seed cans	12.2	0	14.3
	Flexibles	2.9*	16.6	2.9
	Other non-aluminum components	53.8	14.4	54.3
-2"	All non-aluminum components	31.0	22.1	28.5
	Totals	100.0	15.1	100.0

*75 items were found in 80 lb of feedstock.

The results shown for efficiency and product rate are probably somewhat greater than those expected for normal operating conditions. One of the reasons for this is the fact that all magnetic material had been taken out of the feedstock used in the test runs. There is always a regular cycling of the Al Mag magnets off-and-on in order to release whatever attracted magnetic material there may be. When an occasional piece of tramp iron is attracted by an Al Mag magnet during its "on" period, it remains attracted until the magnet cycles "off." The period in which the piece of tramp iron is held by a magnet is accompanied by reduced magnetic strength in the Al Mag air gap (shunting) and a possibility that the iron will cause a partial blockage which will result in the pushing of contamination off the belt and into the Al Mag product. Since no magnetic material was present in the test feedstock, these latter performance reducing conditions did not exist. The magnet off-cycle clearly has an effect on efficiency. Even though there was no magnetic material, the magnet off-cycle feature still operated and had an effect on efficiency. As a result of this feature, which is built in, the full magnetic strength of the four sets of magnets was only available 93.2% of the time.

Beyond the absence of magnetic material in the test feedstock, the non-aluminum can portion of the feedstock was also unusual since it was prepared from un-air classified shredded refuse and contained much aerodynamically light material (much paper, plastic film, etc.) which produced a lower density feedstock than normally; hence, it would less likely impede aluminum can recovery. The aluminum seed cans used were also unusual compared to those from normal operating conditions in that there was little variability in size, weight, contamination, and shape within each shape category. These seed cans were virtually free of tears compared to those in normal feedstock; this enhances the eddy current phenomenon upon which the separation is based.

Finally, the hand-feeding technique used in the test runs produced a somewhat more uniform feed rate than that usually observed; therefore, there were probably fewer losses to the Al Mag plowovers and less impediment to can recovery. With the exception of the can shape difference, none of these biases is considered significant in terms of affecting the test results. It is not possible from the information available to estimate the impact of any of the relative uniformity in can shape, particularly in the category labeled deformed. Other Al Mag operating conditions which would affect the magnets' strength, such as magnet cooling water temperature and supply voltage, did not vary appreciably among all test runs.

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Referring to Table 2, which presents Al Mag efficiency, it can be seen that efficiency dropped somewhat as belt speed increased (length of time a can was in the magnetic field and the time to discharge into the product chute decreased) for both the regular feedstock runs and the run with seed cans along. The decrease in efficiency, five percentage units, as the belt speed was increased is probably significant; had lower and higher belt speeds been used, the difference presumably would have been more pronounced. The wide disparity in efficiencies for flattened cans in replicate Runs 1 and 2 at 400 and 500 fpm is not understood; additional runs might have shown the lower values to be outliers in the statistical sense.

The consistently higher efficiencies for the seed-can-alone runs, compared to those with the entire feedstock, is a basic indicator of the degree of burden-caused impediment, typically about eight percentage units difference in efficiency. Comparing the efficiencies at 400 fpm between the test reported here and the comparable (same volumetric feed rate and belt speed) test run earlier indicates a substantially higher efficiency: 79.3% (this test), 76.7% (other test) for flattened cans, 84.6 (this test), 56.8% (other test) for deformed cans, and 98.3% (this test), 88.3% (other test) for whole cans. For the composite efficiencies, the comparison is 85.3% (this test),63.9% (other test). Since approximately 70% of the cans are in the deformed category, the roughly 20 percentage unit improvement in efficiencies experienced here is the driving factor underlying the increase in composite efficiency.

Referring to Table 3, which shows product rates, one sees, as a result of roughly 5% decrease overall in aluminum product rate between the 500 and 300 fpm belt speeds, a small effect on productivity. However, there is a significant difference between product rate for this test series and the earlier one. Again looking at the comparable 400 fpm belt speed composites, the product rate in the earlier test was 280 lb/hr. This is the amount recovered from aluminum can opportunities of 438 lb/hr. In the new series of tests, the product rate, at 390 lb/hr of opportunities,was 330 lb/hr. Adjusting this upward to equalize the opportunities (using a factor of 1.12*), increases the figure to 271 lb/hr. This is a one-third increase in productivity. Slowing the belt

*Previous comparable test feed 10.95 lb of aluminum seed cans in 1.5 minutes or 435 lb/hr. Current test fed 9.74 lb of seed cans in 1.5 minutes or 390 lb/hr; hence the 1.12 factor (438/390) to adjust current test seed can opportunities to the comparable previous test opportunities.

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to 300 fpm and holding the feed rate constant, as was done in the second series of tests, yields a product rate of 395 lb/hr, an even more impressive improvement.

Table 4 displays loose contamination in the Al Mag product for the test runs. The level of contamination was well below the 40% specified by the manufacturer, but considerably higher in "lights" than that found in the comparable previous test, 8.6% compared to 1.7%. This again, is attributed to the fact that the material was lighter; therefore, for the current test, an exiting can would be more likely to push or carry out with it this lighter material than the more moist material of the earlier test. One would expect a higher level of contamination at the lowest belt speed (highest conveyor burden); however, little difference was observed. At speeds considerably lower than 300 fpm, this phenomenon might be observed. Most of the contamination would be removed by the subsequent pneumatic cleanup steps. [3]

Table provides some characteristics of the Al Mag feedstock used in the current test. As mentioned earlier the seed can weight concentration was more than twice that of the previous comparable test but the same by volume concentration. The 75 "flexible" items (bread wrappers, paper towels rags, etc.) were 45% fewer in number than in the previous test, 55% less in weight concentration, hence lighter per item due in part to significantly lower moisture content (16.6% moisture compared to 53.3%). The moisture content of the entire feedstock was 15.1% compared to 41.2% in the previous test. However, the difference in moisture content does not account for all of the difference between the two tests' feedstocks since the moisture-free feed rate for equivalent volumetric flow rate tests would be 1.4 tph for the current test and 2.4 tph for the previous test. Most of the remaining difference is explained by the proportion and composition of the -2" material in the feedstocks; 31.0% for the current test and 67.2% for the previous test. A significant part of the -2" material in the previous test was glass, whereas almost no glass was present in the current test feedstock.

The intuitive feeling is that glass in the burden has little effect on productivity, i.e., it is not a significant impeder. Hence, the fact that there was glass in the feedstock used in the earlier tests, and since glass is essentially moisture-free, highlights the difference in character of the organic portion of the feedstock between the two tests. Organics in the first test series were dense; much, but not all, of which was caused by moisture. As pointed out above, the material itself was denser, as shown by the figures on dry-basis throughput.

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A continuing program of modifications is underway to reduce the burden by screening out -2" material and to reduce the number of flexibles through the use of deragging devices.
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